Studies on Health Benefit Estimation of Air Pollution in Korea

prepared for Expert Workshop
on Assessing the Ancillary Benefits and Costs of Greenhouse Gas Mitigation Strategies

27-29 March 2000
Washington, DC

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Abstract

In Korea few previous studies on environmental benefit estimates have been carried out. In particular, no studies have dealt with ancillary benefit of GHG reduction. In this context ancillary benefit study proposed would i) play a critical role in cost benefit analysis of climate change by giving a reference of benefit estimates such that it will have a significant impact on climate change policy decision and ii) give a good example on environmental benefit estimation in general and calculation of ancillary benefit in a context of climate change in particular. Recent cost benefit study carried out in Kyonggi Province has revealed a mitigation cost of 3,069 million US dollars and benefit of 743 – 2,069 million dollars associated with mortality and morbidity reduced from PM10, SO2, and O3 over 2000-2007. In developed countries PM is generally regarded as most deleterious pollutant. However, in Korea most epidemiologists have consensus that ozone is the most harmful pollutant. Since, ancillary benefit modeling in Korea is in its fledgling stage, suggestion for the model building is timely and useful. Based on Korean situation of data availability, risk potential, and feasibility, the main frame of future Korean study is recommended to investigate in order of priority PM10, SO2, NO2, and ozone as pollutants and Seoul Metropolitan area, urban area, and nationwide in geographic level to cover.

Keyword: Ancillary benefit, Health benefit, Korea, Bottom-up approach.

To date, previous Korean studies on environmental benefit estimates have been carried out in less-comprehensive way: They have been concerned at local dimension, with focusing on either economic valuation or physical impacts. In particular, no studies have dealt with ancillary benefit of GHG reduction. In this context implementation of ancillary benefit study newly proposed would i) play a critical role in cost benefit analysis of climate change by giving a reference of benefit estimates such that it will have a significant impact on climate change policy decision and ii) give a good example on environmental benefit estimation in general and calculation of ancillary benefit in a context of climate change in particular.

The purpose of this study is i) to review economic assessments studies on air pollution studies in conjunction with climate change policies carried out in Korea, ii) to illustrate a result of cost benefit analysis of air pollution control programs in Kyonggi province, and iii) to suggest a framework of Korean ancillary benefit estimation.

The paper first briefly describes air pollution problem in Korea, then review previous and ongoing economic assessment studies and epidemiologic works carried in Korea in context of climate change. Next, results of empirical study to deal with Kyonggi Province air control programs are revealed with costs and benefits of mitigation options. In the subsequent section modeling framework for ancillary benefit estimation in syntax of Korea is suggested. The last section concludes the paper.

Air Pollution in Korea[1]

Of particular concerns are urbanization, economic growth, energy use, and trans-boundary pollutants when analyzing air pollution issue in Korea. The population of Korea is over 46 millions in 1998 and national area accounts for 99,373 km^2. As a common situation in other countries, air pollution problem is more prevalent in urban areas than in rural areas. Especially large cities whose some air pollution is epidemiologically over threshold level are susceptible to air pollution change. In this vein six large cities in Korea are worthwhile to be paid attention in air pollution context. They include Seoul, Pusan, Taegu, Inchon, Kwangju, and Taejon, all of

[1] See Tables 1 and 2 for statistics on this section.

whose population is over one million, 10 million for Seoul to 1.3 million for Kwangju in 1998. The sum of population of six cities 22million accounts for almost half total population in Korea. Also, their regional pollutant emission takes 28 percent of total national emission amounts, while the total area of six cities is only four percent the national area . The high density of urbanization in Korea has a close linkage with air pollution control issues along with economic growth and energy use. Korea has undergone around ten percent annual economic growth until mid-1990s and is projected to sustain high growth in the forthcoming decades. Korea economic structure is characterized with high energy density associated with most fossil-fuel energy, implying that emissions of greenhouse gases vis-à-vis conventional air pollutants will increase in economic growth unless current fossil-fuel-oriented economic structure changes. Table 2 illustrates projected national pollutant emissions from 1994 to 2005 by pollutant and sector. The pollutant emission keeps increasing in aggregate term through 2005. Of the pollutants concerned, NOx, HC, and TSP emissions increase while SO2 keeps decreasing but increases in 2005 and CO increases until 2000 but decreases in 2005. By sector, transportation is responsible for almost half total emission. Transportation is an important factor in air pollution perspective in the sense that it is mobile pollution difficult to control and that the vehicle registration will keep going up for the time being in Korea. While urbanization is area-specific and economic growth and energy use pattern is structural problem in national level, air pollutants moving from China proposes Korea to take international approach. Streets et al.(1997) point out that about 13 percent of acid rain in Seoul Metropolitan area is contributed from Northeast China.

Environmental Studies in Korea

An important reason for controlling air pollutants such as particulate matter, ozone, or sulfur dioxide is the damaging effects(avoided cost) they have on human health(Cropper et al. 1997). In order to evaluate the impact and damage cost of pollutants in connection with greenhouse gas emissions, two modeling approaches are generally taken (Jacobsen 1998, Aunan et al.1998). Top-down approach (T-D), represented by computable general equilibrium (CGE) models is particularly suitable for analyzing the impact of indirect measures, such as taxes, on main macroeconomic variables. From the predicted changes in economic activity the emission reductions are deduced and the benefits from these reductions may be feed back into the macroeconomic variables. Meanwhile, B-U approach focuses on specific abatement measures considered appropriate for solving a problem. Their potentials for reducing adverse exposure of recipients (people, crops, forests, materials, etc.) and thereby damage, are estimated. Assessments of the values of the costs and benefits are then made according to observed or estimated market prices. The T-D and the B-U approaches both have major weaknesses: While T-D analyses tend to oversimplify for instance the biogeochemical relations, the B-U analyses tend to oversimplify, or simply leave out, macroeconomic relations and consequences. B-U approach has advantages in explicit valuation of environmental amenities and provides means to assess environmental values not directly related to damage costs (Aunan et al., 1998). The principal steps of B-U approach in case of benefit valuation of air pollution reduction can be grouped as follows:

1. Emission: Specification of the relevant technologies and the environmental burdens they impose (e.g. kg of NOx per GWh_e emitted by power plant);
2. Air dispersion: Calculation of increased pollutant concentrations in all effected regions (e.g. incremental concentration of PM, using models of atmospheric dispersion and chemistry for PM formation) ;
3. Impact: Calculation of the concentration from the increased exposure and calculation of impacts (damage in physical units) from this concentration, using a concentration-response function (e. g. cases of mortality and morbidity due to this increase in PM);
4. Valuation: The economic valuation of these impacts (e. g. multiplication by the cost of a case of morbidity, value of statistical life by contingent valuation method) (Rabl and Sparado 1998,1999).
5. Extrapolation: Generalization of a site-specific result to cover other areas in policy making, if necessary.

Figure 1 illustrates B-U approach diagram associated with greenhouse gas mitigation policy and measures(PMs) in a cost benefit analysis framework. With introduction of policy and measures to meet environmental goal and/or national commitment of greenhouse reductions, economic sectors are generally expected to contract their activities, consequently resulting in decrease in economic gains or gross domestic products (GDP). This is a broad concept of cost attributed to the implementation of PMs. In B-U approaches the cost indicates compliance cost to fulfill the condition of the PMs suggested. Even though it does make economic sense to compare the economic cost covering direct (compliance cost) and indirect effects with environmental benefit calculated through B-U analysis, it requires a huge amount of data work not to mention modeling efforts. It is noteworthy when comparing costs and benefits it is important to employ assumptions consistent with those underlying the assessment of GHG abatement costs (Burtraw and Toman 1997).

When analyzing air pollution control policies and measures, several key elements among others are imperatives in order to acquire the credibility of the study. Emission inventory seems a starting points for a scientific investigation of the pollution control. In Korea, no national scale emission inventory has been carried out. In this respect, an ongoing national inventory sponsored by Korea Ministry of the Environment is drawing wide attention, which is expected to be over by 2000. Air quality modeling has focused on primarily SO2, NOx, TSP and PM10. Taking into consideration significant health impact of ozone in Korea, however, ozone modeling has been rarely attempted without credible results. As for end-points impact study, several health effects have been investigated to suggest concentration-response relation on TSP, PM10, ozone, and SO2 (Kwon 1999, Kwon et al.1999, Lee et al.1999a, 1999b, Sung et al. 1998, 1997, and KEI 1998). Table 3 summarizes results of previous epidemiological studies carried out in Korea. Here, relative risk 1.05 in ozone means if ozone concentration increases 100 ppb the number of death increases 5%, asthma 38%.

In economics arena, according to Joh and Yun (1999), since the last decade, the economic studies dealing with climate change in Korea have produced one doctoral dissertation, 25 journal articles, and 10 research reports. Most studies have focused on industry analysis in a context of carbon mitigation and its impact on profits. Naturally, such an energy economics approach has narrowed down the subject to economic cost of climate change. Contingent valuation studies by You et al. (1998) are rare exceptions to estimate environmental benefits of climate change. Among environmental benefit studies, KEPCO (1997) has been regarded as one of the most comprehensive studies. Its main objective was to derive effective energy-related research and policy making by setting its goal to maximize total social welfare via considering social cost of the electric power industry. For the environmental benefit estimation, it applies willingness to pay approach based on damage function framework to be utilized in multi-attributes utility theory. The calculations are made covering mortality, morbidity, dust, visibility, agricultural yields, and global warming for each pollutants such as SO_2, NO_2, TSP, and CO_2 (see Table 4). The limitation of the study is that the damage functions applied came from foreign studies. Only CVM study was carried out for the project. Eom (1997) estimates value of human-life calculating costs of safe-belt in vehicles. She sets time costs equal to value of time (driver's wage rates) multiplied by a time spent on fastening the belts. It is assumed that it takes eight seconds to fasten seat-belt. With variations of ratio of values of driving hours to wage rates (a) and daily driving numbers (f), 451 million Korean Won or 0.4 million dollars is proposed for a value of human life in case of (a, f) (see Table 5). Cho and You (1996) derive social cost of NO_2 associated with respiratory diseases. Based on medical costs and wage-loss, the costs of respiratory is 410,457 million Korean Won or 357 million dollars in national level. Recent study by Jun (1999) addresses the relationship between criteria pollutants (O_3, CO, NO_2, PM_{10}, and SO_2) and medical insurance data for asthma and heart failure (see Table 6). The study utilized data Jan 1996-Nov.1997 in Seoul including meteorological variables and average daily concentrations of the air pollutants. In the cost of illness analysis were included direct costs of medical treatment and indirect costs such as productivity loss, family cost, professional caregiver cost, traffic cost, and various kinds of time cost. The results reveal 1) all the air pollutants except for SO_2 were significantly associated with the daily medical services, 2) O_3 and CO associations were strongest, followed by NO_2 and PM, and 3) The total estimated costs of illness for the two diseases were 27.2 billion Korean Won as of 1997 term or 24 million dollars.

Table 7 illustrates recent economic assessment studies in context of climate change in Korea. The direct goal of the studies is to reveal benefit estimates and further to show economic reference for making policy choice of mitigation commitment in national scale. The aggregate figures of costs and benefits are on this purpose main factors to draw a broad picture for the Korea. As for cost estimation, a co-project leading by Korea Environment Institute (KEI) and Korea Energy Economics Institute is a representative one (Study 1). Study 3 takes a comprehensive framework to address climate and sea level changes and their consequent impacts on ecosystem, water quality, and agriculture, and socioeconomic sector is incorporated to draw research agenda for climate change in Korea. A new project (Study 5) to combine costs and benefits in a comprehensive way has been just launched to seek for optimal mitigation path incorporating costs and benefits from reduction of greenhouse gases.

Of particular component related to the studies is benefit changes in terms of implementation of mitigation options. Study 2 is not empirical one but suggests a conceptual framework. Pursuing estimating empirical benefits from reduction of greenhouse gases is strongly required. International Co-control Analysis Program (ICAP) (Study 4) for Korea is in this vein a right one. It started October 1999 to continue till 2000. It is a pioneer project to deal with PM10's impact on mortality and morbidity in Seoul Metropolitan area through 2020, taking impact path way approach: mitigation scenarios, emission inventory, air dispersion modeling, health impact, cost of illness and willingness to pay as valuation method. Currently, The Korean Ministry of Environment (MOENV) has initiated an ancillary benefit project (Study 6). With the Study 6 we would have tripartite structure of benefit studies on climate change in Korean context: The Study 2 plays a main role in establishing basis for designing project scheme, the ICAP focuses on PM10 and Seoul area. The scope and depth of Study 6 is expected to reflect results and lessons from the previous two studies from the beginning of the study.

Empirical Study: Kyonggi Province Air Control Program[2]

In Korea, no cost-benefit analysis until recently has been carried out taking impact path way approach integrating emission inventory, air concentration, health impact, and valuation modules in a framework. The cost benefit analysis of Kyonggi Province Air Control Program is in this vein recognized a pioneer work to estimate costs and benefits simultaneously on air control program. The Program is a part of 21st Century Kyonggi Province Air Control Program. The program has been initiated when Ministry of the Environment has designated Seoul, Inchon, and 15 cities in Kyonggi as Air Quality Management Areas in July, 1997. The three areas should submit an action plan for air pollution control programs to secure central government's

[2] The estimation model in GAMS format is available from the author upon request.

environment budget (KYDI 2000). Kyonggi province is contiguous to both Seoul, capital of Korea with 10 million population, and Inchon with 2.4 million (see Table 1 for details). Most part of Kyonggi is composed of Seoul Metropolitan area. Kyonggi's population is 8.7 million as of 1998 which accounts for almost 20 percent the national total. In terms of pollution, Kyonggi is large emission source emitting 13 percent total national emission while Seoul is nine percent. Main assumptions made for the study are compared to 1997 in Kyonggi area i) population increases 1.5 times, ii) vehicle registration 1.8 times and iii) final energy consumption increases annual 10 percent from 1993-2001 and 4.2 percent 2001-2010 (KYDI 2000). In terms of emission reduction for pollutants, SO2 mitigation is achieved most in energy sector including industry, generation, and heating. Compared to business as usual, it is assumed in the energy sector 39.6% reduction of 40.6% in 2002, 36.8% of 38.3% in 2007. This is primarily resultant from implementation of low sulphur fuel use. NO2 emission is reduced mainly from transportation sector: 25.2% of 25.6% in 2002 and 36.9 % of 37.3%. Transportation also makes a large contribution to CO reduction: 37.7% of 40.4% in 2002 and 55.3% of 57.5% in 2007. PM10 emission is controlled in fugitive dust of road and transportation: by fugitive dust option, 11.7% of 16.6 in 2002 and 30.15 of 36.6% in 2007. Reduction of VOC emission takes place in transportation (19.5% of 33.4% in 2002 and 28.3% of 45.6% in 2007), VOC abatement facility in industry (8.6% in 2002 and 12.5% in 2007), and incinerator (5.3% in 2002 and 4.7% in 2007).

The pollutants covered in the study include O3, NO2, TSP, PM10, CO, and VOC in emission inventory and used ISC3 model to estimate the concentration of PM10 and SO2 and for O3 UAM and STEM-II models were applied. For economic assessment GAMS program has been utilized. In this study 15 urban areas which is designated as Air Quality Management Areas have been selected for the work. The main purpose of economic assessment for the project is to derive costs from mitigation options and benefits from reduced pollutants 2000 through 2007 year, of which 2002 is short-term target year and 2007 a long-term target year.

Cost Estimation

Total 34 mitigation options are analyzed to reduce air pollution. Table 8 illustrates 34 mitigation options, among which shaded options indicates no-costs or negligible ones. Mitigation options can are classified into six groups: Air management system, urban planning, mobile sources, emission sources, VOC management, and air policy. Air management system approach includes developing emission inventory system, monitoring system for local area, road-side, VOC, TMS, air information system, among others. Urban planning approach focuses on facilitating green area in public parks. Mobile source management is key element to control in urban areas. Introduction of CNG buses is one of the most attractive measures. Vehicle inspection will be more tightened to control emissions. As for demand side management, transferring system and bike-road are recognized primary options. Emission source management focuses on low sulfur fuel use, reduction of smell around industrial complex, and incinerator management. Regarding VOC management, abatement equipment of VOC is applied. Air policy approach includes increasing manpower in the air control administration and education for public involvement.

Costs are distinguished into operation and maintenance costs and investments. All figures indicate additional costs due to mitigation options expressed as net present value of 2000. Cost for option j takes, therefore, following forms,

$$Cost_j = \sum_{y=2000}^{2007} \frac{OMC_j^y}{(1+r)^{y-2000}} + \sum_{y=2000}^{2007} \frac{INV_j^y}{(1+r)^{y-2000}}$$

where *Cost* is additional cost from implementation of option *j* over period 2000 through 2007;
OMC is operation and maintenance costs;
INV is investment taking place when introducing new facilities such as CNG buses, pavement of bike-road, or VOC equipment;
r is annual discounting rate of 8.5 percent.

Data for costs are obtained from various sources: Market information such as fuel prices, CNG bus price; government document for building bike-road plan; experts judgement such as 10 percent of total cost of planting trees is regarded as air pollution control costs. Table 8 shows costs estimates by options for 2000-2002 and 2003-2007. The total cost over 2000-2007 is estimated 3,069 million US dollars with 1 US dollar = 1,150 Korean Won as net present value of 2000 in case of annual discounting rate 8.5 percent. In aggregate term, option of clean fuel use requires the largest cost(1,591 million dollars), followed by CNG vehicle(382 million), preventive equipment for bad smells in industry complex(275 million), and bike-road(143 million). Of the total cost, 1,348 million dollars will be spent on investment side including purchasing CNG vehicles(325 million), establishing preventive equipment for bad smells in industry complex(275 million), building bike-road(143 million), and installing VOC equipment(123 million). Operation and maintenance costs come most from clean fuel use (1,591 million dollars).

Benefit Estimation

As for benefit estimation, only morbidity and mortality are calculated in connection with PM10, SO2, and O3. In order to calculate economic valuation, cost of illness and willingness to pay figures from previous studies are utilized in benefit transfer manner. The motivation of the project is rather different from that of GHG policy in that the former estimates direct benefit of mitigation of criteria pollutants while the latter is related at additional benefit from reducing GHG mitigation options. However, in modeling sense they are identical in having a framework, mitigation option - emission inventory - air concentration - health effect - economic valuation.

Excess annual cases = *(RR-1)* x *Poli* x *Ba* x *Popi*

where *RR* is relative risks;
Pol_i is changes in concentration level in area i;
Ba is basal rate; and
Pop_i is population in area i.

RR indicates relative risks obtained from Korean epidemiological studies. For example, if value of RR for 100ppb for SO2 is 1.05, it means excess occurrence will increase five percent compared with basal rate.

In order to calculate an estimate additional number of premature deaths due to change in a pollutant, a baseline mortality rate is used. For this assessment, the estimates are made in terms of annual cases, so we use the current annual average nonaccidental mortality rate as a baseline basal rate. In this study 5.5 per 1000 is used for each case. Pol*i* is changes in concentration due to air control activities in area i.

The types of morbidity analyzed include asthma inpatient, asthma outpatient, heart failure inpatient, and heart failure outpatient. The population is grouped children(0-14 years), the young(15-64 years), and the old(65 over). The relative risks in case of 1 ppb or 1 μg change are shown on Table 9. Note that relative risk values of mortality for each pollutant are identical regardless of ages while morbidity values are differentiated according to cost of illness results by Jun(1999). Here, cost of illness includes user charge, reimbursement as direct cost and income lost, patient visiting time cost, family cost, attendant cost, and others as indirect cost for inpatient, patient visiting time cost, patient waiting time cost, and travel cost for outpatient.

Table 10 shows willingness to pay for mortality and cost of illness for morbidity. For mortality two mean values are suggested: 0.4 million based on Eom(1997) and US EPA's value of 4.8 million dollars, which per capita GNP difference ($6,823 for Korea and 30,246 for US in 1998) is adjusted to yield 1.1 million dollars for Korean value. Mortality values for each age group have been arbitrarily given, 60 percent mean value for children, 100 percent for the young, and 70 percent for the old.

Taking valuation for mortality changes for SO2 in year 2002 area A as example, A's population is 1.1 million, *Ba* applied is 5.5 per 1000, and a SO2 concentration decreases by 5 ppb with implementation of mitigation options, the calculation is as follows,

$$\begin{aligned}\text{Excess Occurrence} &= (RR-1)\text{x Poli x Ba x Popi}\\ &= (1.05-1)\text{x}(5/100)\text{x }(5.5/1000)\text{x}(1.1\text{million})\\ &= 15\end{aligned}$$

That is, air control program is estimated to result in decreasing 15 deaths associated with SO2 in area *i* in 2002.

Table 11 summaries aggregated results of excess occurrences and benefits of morbidity and mortality 2000-2007 years. The total benefit from reduced mortality and morbidity due to implementation of air control programs in 15 areas in Kyonggi Province 2000 through 2007 as net present value of 2000 as annual discount rate of 8.5 percent is 743 million dollars or 2,069 million dollars depending upon values of premature mortality avoided (0.4 million or 1.1 million). The aggregate excess occurrence of mortality over 2000-2007 is estimated 3,446, among which the O3-induced is the largest 1,754 followed by 1,242 for PM10 and 449 for SO2.

As for excess occurrence of morbidity, O3 also is largest responsible for the morbidity with 15,373 occurrences and PM10 is estimated 3,106 excess occurrences. Concentration-response relation for SO2 in Korea has not been reported so that estimation for SO2 has not been made. In terms of benefits for mortality and morbidity, total benefit is heavily dependent upon mortality. In context of GHG benefit estimation addressed in this study, analysis of morbidity needs to be more intensively scrutinized. The low figure of excess occurrence of especially PM10 is related primarily changes in PM10 concentration between no-control and control scenarios. Comparing benefits of morbidity and mortality, morbidity benefits seem underestimated or mortality benefits overestimated. The ratio of benefit to cost in this study 0.24 or 0.67 depending upon mortality values applied.

The main lessons, with risk of generalization, from the Kyonggi project include 1) there exists serious uncertainty, say, emission inventory, air pollution concentration, concentration-response function in health analysis, willingness-to-pay to mortality, and discounting rate, and 2) it is important to take at least both O3 and PM10 into account in benefit estimation.

Suggestion for Model for Korean Environmental Benefits Estimation

Following is a suggestion for a Korean model framework in empirical level to address environmental benefit estimation from reduction of greenhouse gases[3]. Note that here we focus on environmental benefits out of various ancillary benefits such as financial savings, technology innovation, and others (see OECD 1999 for details). In addition, main interest addressed in this study deals with mainly short-term aspects.

Table 12 describes checklist needed when designing benefit estimation model including data availability, significance, transferability, uncertainty, priority, and feasibility. Data availability is recognized the first and critical step in designing a model. Previous studies should be thoroughly reviewed to decide whether they fit to specific requirement of the model in concern. Significance here refers to how much an item in interest is assumed to be important in terms of magnitude of estimates. For instance, if health impact takes a significant portion in total

[3] For a detailed information on Korea in terms of ancillary benefit modeling, see Joh and Nam (1999).

values related to the benefit estimation model, the health should be analyzed in any manner. Without it, the model *per se* has inherently significant limitation. When there is lack of case-specific data, what we can do is to initiate a project to produce the data. This is a most desirable case[4]. Otherwise we need to borrow the data from previous studies. This is a most usual case occurred. In this vein, transferability is concerned at potential problem when we use outside results. Uncertainty abounds over data, functional relationships, parameters in each module. Taking various factors mentioned above into account, we have to decide which items are included first and next in empirical work. It is a priority concern. There shows trade-off between scope and depth of a research and resources constraints of the research. Feasibility refers to practical possibility that any specific item can be modeled considering the above five criteria.

Taking PM as example, the feasibility is high means we can include PM10 in modeling framework: No significant problems exist to analyze it. While PM2.5 is highly required to analyze in a model (high priority), considering low data availability and low transferability, the feasibility to carry out the analysis of PM2.5 is low. Based on the estimation of the above tables, several concerns are derived in modeling perspective. Main factors to be considered are Priority and Feasibility in the above table. First of all, the items which are evaluated both high in Priority and Feasibility include Energy sector in mitigation scenario and emission modules, PM10 in air quality module, Short-term effect in health analysis, COI and CVM in economic valuation, and Geographic difference and Age difference in Extrapolation module. It implies that they are important enough to be included and can be modeled without serious problem. The problem lies with the items that have high priority but low or middle feasibility. They list PM2.5, O3, Secondary effect for PM in air quality module and Ecosystem and Biodiversity in endpoints sector. Although ecosystem and biodiversity are assumed to be significant in total benefit context, they are mainly concerned at long-term perspective. For this reason, we are relatively comfortable to exclude them in a short-term oriented model. Data on PM2.5 and studies on ozone and secondary effect of PM are almost zero in Korea. For further studies on this issue, they should be regarded as first research agenda to carry out. Reflecting the above observations, we come to propose a modeling framework for environmental benefit model in Korea. As for base

[4]The example includes air dispersion modelling, health analysis, and CVM for Korean ICAP.

year, data availability over sectors is a critical point to be considered. The primary focus of the analysis shall be the Seoul metropolitan area. The main reason behind this is air quality data availability. The effort shall also assess the feasibility of conducting a preliminary analysis for the rest of the country based on extrapolation from the Seoul data. Below are main structure and modules suggested for ancillary environmental model in context of climate change policies in Korea.

Main Structure:

- Scope of Sector (in order of priority) : (Energy), (process), (forestry, agriculture, waste).
- Target media (in order of priority): (PM10, SO2, NOx), (O3), (PM2.5), (Secondary effect)
- Target endpoints (in order of priority) : (Short-term premature mortality (total and respiratory mortality)), (hospital admissions due to cardiovascular and respiratory diseases, unscheduled outpatient visit), (excess mortality rate due to long-term exposure).
- Base Year : 1995.
- Target Year : 2000, 2010, 2020.
- Target Area (in order of priority) : (Seoul Metropolitan area), (national urban areas), (nation-wide).

Main Analysis Modules:

GHG mitigation scenarios: Exogenously given scenarios are applied according to National Action Plans.

Emission inventories and air quality scenarios: Based on the GHG mitigation scenarios, air concentration is estimated with dispersion model.

Health effects analysis: Air concentration-health response function is derived with different cohorts.

Economic valuation of impacts: Contingent valuation method, cost of illness, and averting behavior method is applied to estimate health benefit rising from changes in air quality.

Extrapolation of results of a specific area to country-wide: In case of local study, the potential national benefit is extrapolated in a manner of benefit transfer, if necessary.

Conclusion

Air pollution problem as a by-product of economic activities has been one of the most important environmental agenda to struggle between economic growth and environmental conservation over decades. Recently, when climate change issue has drawn attention, the air pollution control has been recognized in co-control benefit perspectives. The fact that most conventional pollutants come from energy-related activities throw a clear insight that fossil-fuel energy control yields reduction of greenhouse gases(GHG) and local air pollution simultaneously. In economic assessment aspect, most previous studies have focused on abatement costs and pollution changes. The primary reason that benefit studies have been less proposed is of technical difficulty: They require participation from various disciplines and data. However, the circumstances have changed as air pollution has increased up to the detrimental level and epidemiological studies have warned risk potential showing scientifically sound relationships between air pollution and health impact. In addition to them, climate change polices had a catalytic role in boosting air pollution benefit studies, often called ancillary or secondary benefits. The ancillary benefit studies in this context have very practical implication to be utilized to persuade the society that GHG mitigation bring about economic costs but additional benefits. This argument has in one sense political implication especially for developing countries, most of which have been reluctant to commit GHG mitigation in the Framework Convention on Climate Change. However, the air pollution is such a serious that developing countries are enforced to implement a substantial pollution control programs domestically. This requires various information on air pollution, one of which is magnitude of costs and benefits accrued to by the policy implementation. As conventional pollutants are closely linked with greenhouse gas reduction policies, air pollution control is consequently recognized in conjunction with climate change polices. In a series of acquiring knowledge on this interaction, ancillary benefit studies have been carried out most in developed countries and few in developing countries.

In Korea few previous studies on environmental benefit estimates have been carried out. In particular, no studies have dealt with ancillary benefit of GHG reduction. In this context ancillary benefit study would i) play a critical role in cost benefit analysis of climate change by giving a reference of benefit estimates such that it will have a significant impact on climate change policy decision and ii) give a good example on environmental benefit estimation in general, calculation of ancillary benefit in a context of climate change in particular. Korea ICAP (International co-control benefit analysis program) in this context is drawing wide attention from academia as well as policy makers. In investigating PM10's impact on mortality and morbidity in Seoul Metropolitan area through 2020, it takes bottom-up approaches having modules of mitigation scenarios, emission inventory, air dispersion modeling, health impact, and valuation. In a similar methodology but with a view to evaluating air pollution control programs in Kyonggi Province through 2007, recent cost benefit study has revealed a mitigation cost of 3,069 million US dollars and benefit of 743 – 2,069 million dollars, the ratio of benefit to cost 0.24-0.67, associated with mortality and morbidity reduced from PM10, SO2, and O3.

In developed countries PM is generally regarded as most deleterious pollutant. However, in Korea most epidemiologists have consensus that ozone is the most harmful pollutant. Since, ancillary benefit modeling in Korea is in its fledgling stage, suggestion for the model building is timely and useful. Based on Korean situation of data availability, risk potential, and feasibility, the main frame of future Korean study is recommended to include first PM10, SO2, and NO2 and then ozone and secondary effect of PM. In geographical sense to cover for the studies Seoul Metropolitan area is evaluated the first priority followed by national urban areas and the total nationwide area.

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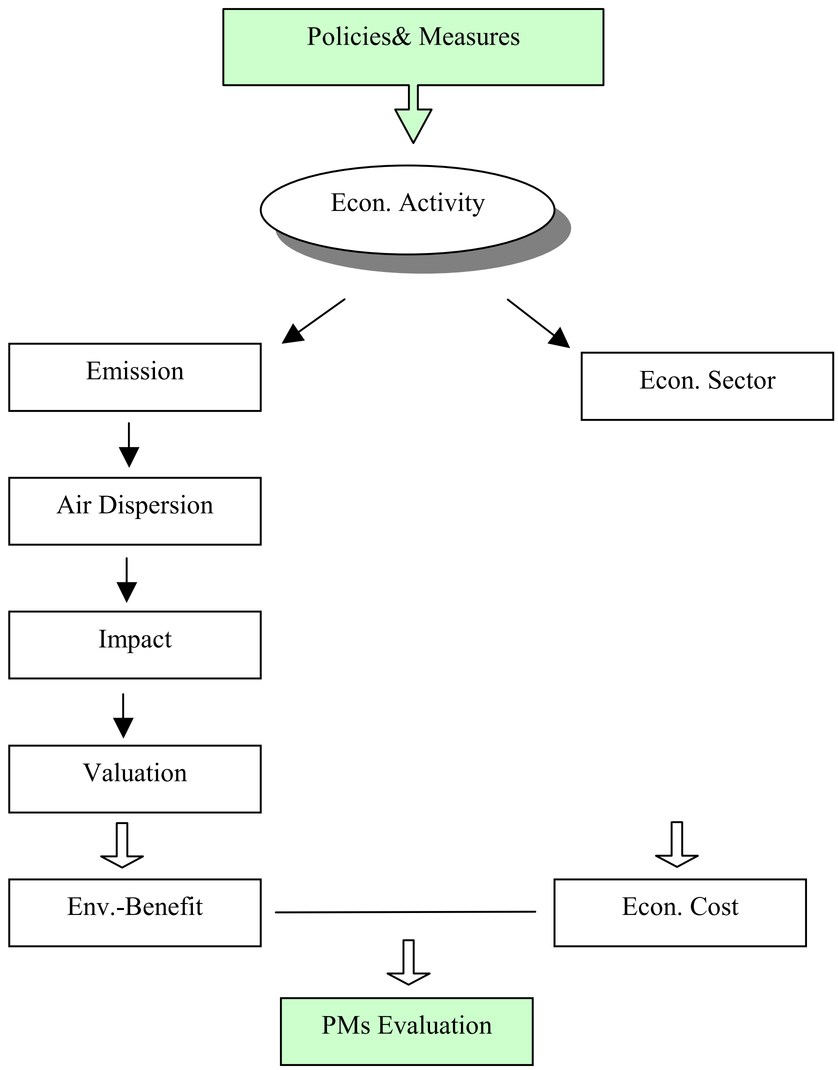

Figure 1. CBA Framework of Bottom-Up Approach

Table 1. Facts on Air Pollution in Large Areas in Korea in 1997

Area		Seoul	Pusan	Taegu	Inchon	Kwangju	Taejon	Kyonggi
1)Pop.(1000)*		10,215	3,837	2,509	2,423	1,313	1,344	8,367
2) Land (km^2)**		606	751	886	958	501	540	10,136
3) Final Energy Products Consumption (10^3toe)***		19,715	7,249	4,374	8,346	1,746	2,018	16,548
4) Pollutant Emissions (ton)****	Total	388,342	352,012	127,925	219,579	57,892	62,917	549,529
	(%)	8.9	8.1	2.9	5	1.3	1.4	12.6
	TSP	14,895	14,644	6,843	9,646	2,634	2,717	27,901
	(%)	3.4	3.3	1.6	2.2	0.6	0.6	6.4
	SO_2	22,514	152,606	16,749	53,692	4,078	7,365	128,078
	(%)	1.7	11.3	1.2	4	0.3	0.5	9.4
	CO	215,211	88,964	58,826	62,221	30,365	31,395	196,507
	(%)	19.1	7.9	5.2	5.5	2.7	2.8	17.4
	HC	29,531	14,281	8,136	9,664	4,007	4,253	28,242
	(%)	18.2	8.8	5	6	2.5	2.6	17.4
	NO_X	106,191	81,517	37,371	84,356	16,808	17,187	168,801
	(%)	8.3	6.4	2.9	6.6	1.3	1.3	13.2
5) Air pollution *****	SO_2 (ppm)	0.011	0.018	0.016	0.013	0.009	0.011	n.a
	TSP (mg/m^3)	72	84	62	86	74	67	n.a
	O_3 (ppm)	0.016	0.019	0.015	0.016	0.021	0.018	n.a
	NO_2 (ppm)	0.032	0.028	0.024	0.026	0.021	0.022	n.a
	PM-10 (ug/m^3)	68	68	72	70	49	69	n.a

Sources:
*www.nso.go.kr:8001/cgi-bin/html_out.cgi?F=Xc78_r5809.html, 10. March, 2000
** www.nso.go.kr:8001/cgi-bin/html_out.cgi?F=X33be_r33be.html, 10. March, 2000
***Yearbook of Regional Energy Statistics, 1998
**** www.me.go.kr/eis/owa/aqmb0203?av_no=19990079&av_code=200, 10. March, 2000
*****www.nso.go.kr:8001/cgi-bin/html_out.cgi?F=X27fa_r2a54.html, 10. March, 2000

Table 2. Projected National Pollutant Emissions by Pollutant and Sector

(Unit: 10^3ton)

	Year	1994	1997	2000	2005
	Total	4,526	4,364	4,942	5,413
1)By Pollutant	SO_2	1,603	1,356	1,104	1,201
	NO_X	1,192	1,278	1,606	1,933
	CO	1,156	1,129	1,528	1,464
	HC	146	162	160	174
	TSP	429	439	544	641
2) By Sector	Transportation	2,152	2,194	2,265	2,412
	Industry	1,333	1,175	1,453	1,618
	Generation of Electricity	643	746	698	850
	Heating of house	398	249	526	533

Source: http://www.me.go.kr/eis/owa/aqmb0203?av_no=19990079&av_code=200, 10. March, 2000

Table 3. Relative Risks for Pollutants in Korea in case of Changes in 100ppb(or u*g)*

	Mortality	Morbidity
O_3 *100ppb*	1.05(1.02-1.11)	1.38(Asthma*) 1.50(lung cancer *daily excess numbers)
TSP *100ug*	1.03	1.60(asthma*)
PM_{10} *100ug*	1.02	1.12(all respiratory)
SO_2 *100 ppb*	1.05(1.02-1.08)	Not certain

*Maximum estimates

Source: Kwon 1999, Kwon et al.1999, Lee et al.1999a, 1999b, Sung et al. 1998, 1997, and KEI 1998.

Table 4. MAUT/CV WTP

(Unit: $/ton/year, 1US$=1,150 Korean Won)

Pollutants Attributes	SO_2	NO_2	TSP	CO_2
Mortality	148.9 (131.5-166.4)	72.9 (64.4-81.5)	595.8 (525.9-665.7)	
Morbidity	15.3	561.8	547.3	

	(13.2-17.3)	(485.5-638.1)	(473.0-547.3)	
Dust			1272.1 (1111.4-1432.8)	
Visibility	10.4 (9.0-11.7)	9.3 (9.3-12.0)	127.1 (110.9-143.4)	
Crops	53.2 (47.3-59.1)			
Global warming				2.2 (2.0-2.5)
Total	227.8 (201.0-254.6)	645.4 (559.1-731.6)	2542.4 (222.1-2863.6)	2.2 (2.0-2.5)

*Parentheses show values in confidence level.
Source: Table III-37, KEPCO(1997).

Table 5 . Estimates of Value of Life in Korea

(Unit: 1,000$)

f a	1.3	1.8	2.0	2.5
0.3	155.7	204.3	250.4	334.8
0.4	250.4	325.2	<u>392.2</u>	519.1
0.5	334.8	476.5	519.1	745.2

*a is ratio of values of driving hours to wage rates, f is daily driving numbers.
Source: Table 5, Eom (1997)

Table 6. Total Cost of illness for asthma and heart failure attributable to air pollution, Seoul, 1996. 1 - 1997. 11

(Unit: 1,000$*)

Pollutant	Asthma	Heart Failure	Sub total
O_3	5,860.9	1,304.3	7,165.2
CO	15,400.0	556.5	15,956.5
NO_2	121.7	104.3	226.1
PM10	304.3		304.3
Sub total	21,687.0	1,965.2	23,652.2

*monetary value of 1997
Source: Table 20, Jun(1999)

Table 7. Recent Economic Assessment Studies on Climate Change in Korea

No	Title	Main Contents and Methodology	Leading Research Institutes	Period
1	CGE approach to GHG mitigation options	Domestic and global CGE for mitigation costs	KEI and KEEI	Jan.'99-Aug.'00
2	A conceptual framework of ancillary benefit modeling in context of climate change in Korea	Conceptualization and suggestion for Korean modeling	KEI	Jan. '99-Dec.'99
3	Policy design for climate change impacts and adaptations	Master plan for the climate change policies	KEI and K-JIST	Jun.'99-Mar.'00
4	An analysis of air pollution control benefits estimation of reduction of GHG - International co-control benefit analysis program for South Korea	Seoul Metro area focused on PM10 using impact pathway approach	KEI and KIST	Oct.'99-Sep.'00

5[a]	Development of optimal policy schemes for GHG reduction	CGE with integration of ancillary benefits	KEI	Jan.'00-Dec.'01
6 [b]	An analysis of air pollution control benefits estimation of reduction of GHG - Nationwide Study	Nationwide impact pathway approach	KEI	Apr.'00-

a On-going study to be subject to change
b Under consideration to be subject to change
KEI: Korea Environment Institute
KEEI: Korea Energy Economics Institute
KIST: Korea Institute for Science and Technology
K-JIST: KwangJu Institute for Science and Technology
MOENV: Korea Ministry of the Environment

Table 8. Mitigation Options and Costs in Kyonggi
(Net Present Value of 2000, Discount rate: 8.5%, Unit: 10^5\$)

Mitigation Options		Main Contents	2000-2002			2003-2007			Total		
			Invest	O&M	Sum	Invest	O&M	Sum	Invest	O&M	Sum
Air Management System	Dev. Em. Data	1) Develop Emission Inventory System	3.1		3.1	4.4		4.4	7.5	0.0	7.5
	Dev. Monitoring System	2) Local Monitoring	9.2		9.2	9.6		9.6	18.8	0.0	18.8
		3) Road Monitoring	9.2		9.2	1.6		1.6	10.8	0.0	10.8
		4) VOC Monitoring	17.1		17.1	16.0		16.0	33.1	0.0	33.1
		5) Area Monitoring	2.2		2.2	3.5		3.5	5.7	0.0	5.7
		6) Air Monitoring Signal	1.1		1.1	1.3		1.3	2.4	0.0	2.4
	Dev. Air Info. Sys.	7) TMS	551.4		551.4	271.2		271.2	822.6	0.0	822.6
		8) Air Info. System	1.5		1.5	3.0		3.0	4.5	0.0	4.5
Urban Plan-ning	Env. Sound policy	9) Pre-Environmental Impact Measures									
	Green Area	10) Green Area for Public Park	715.2		715.2	259.0		259.0	974.3		974.3
Mobile Source Mgmt.	Low Poll. Vehicle	11) CNG Vehicle	1378	113	1491	187	460	2333	3252	573	3825
	Vehicle Emission Control	12) Vehicle Inspection	590.3	209.5	799.8	121.3	473.2	594.5	711.6	682.7	1394.3
		13) Obsolescence of Used Car									
		14) Speed Check	55.9		55.9	80.8		80.8	136.7		136.7
		15) Idling Reduction									
		16) Emission Control									
	Demand Side Mgmt	17) Mass Transportation	53.0		53.0				53.0	0.0	53.0
		- Train System - Transfer System	4.2		4.2	3.6		3.6	7.8	0.0	7.8
		- Bus Only Lane			0.0						
		18) Bike Road	646.8		646.8	781.2		781.2	1428.0	0.0	1428.0
		19) Reduce Traffic Jam									
		-No driving a day per week									
		-Special Area									

		-Charge Fee on Traffic Jam Block									
		-Detouring Road	315.7		315.7	381.3		381.3	697.0	0.0	697.0
		-Traffic System	0.3		0.3	0.1		0.1	0.4	0.0	0.4
		20) Manage Firm Traffic Demand			0.0						
	Metro. System	21) Metro. Traffic Mgmt.	31.3		31.3	35.9		35.9	67.2	0.0	67.2
Emission Sources	Firm Emission	22) Local Emission Standard									
		23) Clean Fuel Use		7027.0	7027.0		8880.9	8880.9		15908	15908
	Reduce PM	24) Washing Vehicle on Construction Site									
		25) Dust Vehicle	23.3	11.0	34.3	17.4	26.9	44.3	40.7	37.8	78.5
		26) Pavement	325.8		325.8	393.5		393.5	719.3		719.3
	Bad Smell	27) Industry Complex (*Sihwa, Banwol*)	2749		2749				2749	0.0	2749
	Incinerator Mgmt.	28) Large Incinerator									
		29) Small Incinerator	228.2		228.2	50.7		50.7	278.9	0.0	278.9
		30) Control Illegal Burning									
VOC Mgmt	VOC Abatement	31) VOC Emission Facility	532.9		532.9	754.1		754.1	1287.0		1287.0
	VOC-content Item										
	ReduceVOC Emis.										
Air Policy	Budget,Manpower	32) Increase Manpower for Air Mgmt.	9.4		9.4	34.0		34.0	43.4	0.0	43.4
	Metro.Air System	33) Metro. Air System	23.1		23.1	43.7		43.7	66.8	0.0	66.8
	Public Involve	34) Public Involvement Program	23.1		23.1	43.7		43.7	66.8	0.0	66.8
	Total Costs		8301	7360	15661	5184	9841	15025	13485	17201	30686

Note: Shaded areas indicate "no-cost."

Table 9. Relative Risks Applied to the Study for Mortality and Morbidity by Pollutants per 1 ppb(1 ug)

	Mortality	Asthma Inpatient	Asthma Outpatient	Heart Failure Inpatient	Heart Failure Outpatient
SO2(0-14 age)	0.0003				
SO2(15-64)	0.0003				
SO2(65+)	0.0003				
PM10(0-14 age)	0.0002				
PM10(15-64age)	0.0002				
PM10(65+)	0.0002		0.006	0.006	
O3(0-14age)	0.0005		0.0038		
O3(14-64)	0.0005		0.0038		
O3(65+)	0.0005	0.0038	0.0038	0.0038	0.0038

Source: Kwon 1999, Kwon et al.1999, Lee et al.1999a, 1999b, Sung et al. 1998, 1997, KEI 1998, and Jun(1999).

Table 10. Willingness to Pay for Mortality and Cost of Illness for Morbidity Applied to the Study

(Unit: Dollar/case)

	Age 0-14	Age 15-64	Age 65+
Mortality with 0.4 million	274,050	400,000	234,900
Mortality with 1.1million	767,340	1,100,000	657,720
Asthma Inpatient	411	825	1,127
Asthma Outpatient	303	458	409
Heart Failure Inpatient			1,107
Heart Failure Outpatient			555

Source: Mortality (0.4 million from Eom(1997), 1.1 million from EPA(1999)).

Table 11. Excess Occurrence and Benefits from Mitigation Options in Kyonggi Province

(Net present value of 2000 as annual discount rate 8.5%)

		2000 – 2002 year			2003 –2007 year			Total
		SO_2	PM10	O_3	SO_2	PM10	O_3	
Excess Mortality	0-14 age	50.9	61.1	157.5	60.6	247	277.6	854.7
	15-64 age	143.7	172.8	445.1	171.3	698	784.8	2,415.8
	65+ age	10.5	12.6	32.4	12.5	50.8	57.1	175.8
	Excess Occurrence	205	246.6	635	244.4	995.7	1,119.5	3,446.2
	Benefit(1) (Million $)	56.9	68.4	176.1	45.1	183.6	206.5	736.6
	Benefit(2) (Million $)	159.3	191.5	493.1	126.3	514.18	578.2	2,062.5
Excess Morbidity	0-14age			1,196.9			2,110	3,306.9
	15-64age			3,383.1			5,964.3	9,347.3
	65+age		42.2	984.5		3,046.8	1,735.7	5,809.2
	Excess Occurrence	0	42.2	5,564.5	0	3,064.8	9,810	18,481.5
	Benefit (Million $)	0	0.4	2.1	0	1.2	2.5	6.2
Total Mortality + Morbidity Excess Occurrence		205	288.8	6,199.5	244.4	4,046.5	10,929.5	21,913.6
Total Benefit (1) (Million $)		56.9	68.8	178.2	45.1	184.8	208.9	742.7
Total Benefit (2) (Million $)		159.3	191.9	495.2	126.3	515.3	580.7	2,068.9

Note: Benefit (1) is the case value of mortality reduced is 0.4 million dollars based on Korean Studies while Benefit (2) is 1.1 million dollars borrowed from US studies after GNP adjusted. The US estimate applies to only mortality estimation.

Table 12. Check List for Building Korean Environmental Benefit Model

	Data Availability	Significance	Transferability	Uncertainty	Priority	Feasibility
Mitigation						
-Energy	H	H	M	M	H	H
-Process	H	M	M	M	M	M
-Forestry	M	M	M	M	M	M
-Agriculture	M	M	M	M	M	M
-Waste	M	M	M	M	M	M
Emission						
-Energy	M	H	H	M	H	H
-Process	M	M	H	M	M	M
-Forestry	L	M	M	H	M	L
-Agriculture	L	M	M	H	M	L
-Waste	L	M	M	H	M	L
Air Quality						
-PM10	M	H	L	H	H	H
-PM2.5	L	H	L	H	H	L
-O_3	L	H	L	H	H	M
-SOx	M	M	L	M	M	M
-NOx	M	M	L	M	M	M
-Secondary	L	H	L	H	H	L
Health						
-Short-term	M	H	L	M	H	H
-Long-term	L	M	L	H	M	L
-Threshold	M	M	M	M	M	M
-C-R relation	M	H	L	M	H	M
Materials						
-Building	L	L	M	M	M	L
Crops	L	L	M	M	M	L
Aquatic	L	L	M	H	L	L
Ecosystem	L	H	L	H	H	L
Biodiversity	L	H	L	H	H	L
Valuation						
-COI	H	H	L	M	H	H
-CVM	L	H	M	H	H	H
-ABM	L	M	L	M	M	H
Extrapolation						
-Geographic difference	H	H	L	L	H	H
-Age differences	H	H	M	L	H	H
-Income difference	H	M	M	L	M	H
-Air concentration	L	H	M	M	H	M

*H: high, M: middle, L: low